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TRENDS IN TOTAL DISSOLVED SOLIDS CONCENTRATIONS AND LOADS IN THE COLORADO RIVER BASIN

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Introduction

The U.S. Geological Survey has conducted several studies of trends in TDS concentrations and loads in the Colorado River basin (Kircher, 1984, Kircher et al. 1984, Moody and Mueller 1984, Mueller and Moody 1984, Liebermann et al. 1989, Butler, 1996, Bauch and Spahr, 1998, Butler, 1998, and Vaill and Butler, 1999). These studies generally show significant downward trends in TDS concentrations and loads in the Colorado River and in many tributaries. Some trends date back to the mid-sixties which would predate the formation of the Colorado River Basin Salinity Control Program in 1972 (fig. 1). Other trends occur at stations that are upstream of salinity control projects (Bauch and Spahr, 1998). Gellis et al. (1991) suggest that sediment and salt loads have been declining in the Colorado River and its tributaries since the mid 1940s. Graf (1986) came to a similar conclusion for sediment in studying the relation between erosion and grazing in the Navajo Nation. The Navajo Nation occupies about 26,000 square miles in the Colorado River basin in northeast Arizona, northwest New Mexico, and southern Utah (Graf, 1986).

Relation to the Forum and the Act

The Colorado River Basin Salinity Control Forum (Forum) was formed in 1972, and the Colorado River Basin Salinity Control Act was passed in 1974 primarily in response to dire predictions of increasing salinity, particularly at Imperial Dam (U.S. Environmental Protection Agency, 1971a&b). In 1975 both the U.S. Department of the Interior (1975) and the Forum (1975) projected increasing salinity at Imperial Dam (fig. 2). In 1984 Mueller and Moody (1984) were able to show that these projections would not be realized and that salinity at Imperial Dam had generally been declining since at least the mid-sixties (fig. 2).

Relation to salinity control projects

The general declining trends in salinity at gaging stations in the Upper Basin cannot be directly related to salinity control projects. This is particularly true for the stations analyzed by Bauch and Spahr (1998) because most were upstream of any salinity control projects. Butler (1996) could not establish a direct connection between the declining trends on the Colorado River and salinity control projects, although he did conclude that a relation was "plausible". Butler (1998) was able show salinity decreases in four small basins with salinity control projects. However, Butler (1998) was not able to separate the decreases due to salinity control projects from other possible contributing factors such as long-term changes in crops, water use, and irrigated acreage.

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Butler (1998) also did not discuss the possible influence of geomorphic and climatological factors that may be responsible for basin-wide trends (Gellis et al. 1991, Graf, 1986, Hayes, 1995). However, Butler (1996) stated that, "Climatic-induced changes in dissolved solids during the period of the salinity-control projects could mask or overwhelm the human-induced changes." Since many trends predate the beginning of salinity control efforts, and since some declining trends show brief periods of increasing salinity after implementation of salinity control projects (fig. 1), there appears to be more influential factors controlling salinity variability in the Upper Basin. Bauch and Spahr (1998) discuss three possible controlling factors, channel evolution and hydrologic variation, changes in ground water contributions, and conversion of agricultural land to urban land.

Channel evolution and hydrologic variation

Gellis et al. (1991) argue that suspended sediment and salt load decreased after the early 1940s in the Colorado Plateau portion of the Colorado River Basin through a combination of channel evolution and hydrologic variation. This decline followed a period of high sediment and salt yield from about 1880-1940 that was caused by arroyo cutting and stream entrenchment in most tributary streams (Gellis et al.1991). During channel evolution sediment production, which is initially high due to incision and bank erosion, decreases because of reduced erosion and sediment storage in the widened channels (Gellis et al. 1991). In the Colorado River basin, this intrinsic evolution and a period of low peak flows from the 1940s to mid 1950s in tributary streams triggered sediment storage and floodplain development, which in turn significantly decreased sediment and salt yields of the Colorado River and its principal tributaries (Gellis et al. (1991).

The conclusions of Gellis et al. (1989) support similar conclusions by Graf (1986). Graf (1986) states that; "From about 1943, sediment yield from the entire Upper Colorado River Basin declined by about 50% corresponding to adjustments in storm frequency and major atmospheric circulation patterns rather than changes in land management." Graf (1986) also states that "...erosion related to overgrazing occurs near dwellings, water sources, and trail routes, but this erosion is localized and unlikely to explain massive changes in sediment and water yields from large drainage basins." Although Graf (1986) did not address salinity, several studies have shown that exposure of newly eroded soil to water is necessary for significant pick up of salinity (Jurniak et al., 1977, Laronne, 1982, Laronne and Shen, 1982, Ponce, 1975, Riley et al., 1982, Shen et al., 1981, White, 1977, Whitmore, 1976). Thus, it can be concluded that basin-wide decreases in erosion would be accompanied by similar decreases in salt loads.

Changes in ground-water contributions

The reach of the Colorado River between the towns of Dotsero and Glenwood Springs, CO represents the largest single source of dissolved solids in the Upper Colorado River Basin (Liebermann et al., 1989). About 500,000 tons/year of salt enter the Colorado River in this reach through thermal springs and direct ground water inflow (Liebermann et al., 1989, Warner et al., 1985, Iorns et al., 1965). The TDS concentration in the ground water comes from dissolution of halite and gypsum within the Pennsylvanian Eagle Valley Evaporite (Kirkham et al., 1999, Chafin and Butler, in press). The total annual contribution from dissolution of the Eagle Valley Evaporite is estimated to be 901,000 tons (Chafin and Butler, in press). This contribution alone accounts for about 81 percent of the annual dissolved solids load at the Colorado River below Glenwood Springs and 60 percent of the load at Cameo, CO. The annual rate of dissolution and delivery of salt to the Colorado River undoubtedly fluctuates about a true mean value. The time series of annual mean values may also be subject to short and long term trends. These fluctuations and trends could have a significant influence on trends detected at downstream locations.

Conversion of agricultural land to urban land

Bauch and Spahr (1998) state that in most counties in the Colorado River Basin there have been changes in land use from agriculture to urban. Assuming that urban land receives less applied water than irrigated agriculture, the conversion to urban land could result in less recharge to shallow ground water and a subsequent decrease in salt loading to the river network. Bauch and Spahr (1998) do not attempt any quantification of this possible effect and do not cite any published studies.

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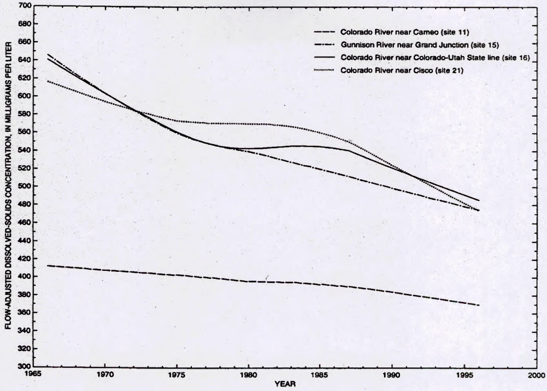

Figure 1. Trends in flow-adjusted TDS concentrations at four stations (from Vaill and Butler, 1999).

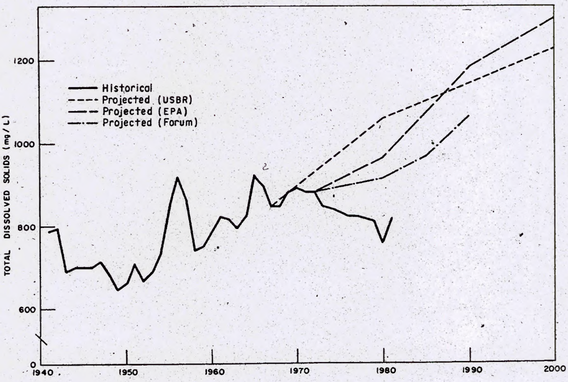

Figure 2. Historical and projected TDS concentrations at Imperial Dam (from Mueller and Moody, 1984).